The Telegraph

AN ESSENTIAL GUIDE TO THE WEATHER

PART ONE

Met Office

Like many people here in the UK, I've always been fascinated by the weather – it's hard not to be in a place with such fantastically variable conditions. From dreary rain to spectacular cloud formations, from balmy summer days to intense Atlantic storms with howling winds and crashing waves, our weather is constantly changing.

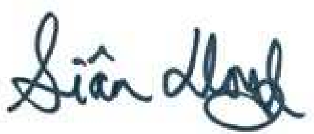
Seeing our weather is one thing, but understanding what you are witnessing – and why it is happening – makes it all the more captivating.

In this booklet we give an insight into how weather works and why it happens in the first place. What are the global atmospheric systems driving the weather and how do weather fronts form?

You'll also discover how to identify different types of cloud – from fluffy cumulus to ragged stratus fractus – and what they can tell us about the weather heading our way.

All of these questions and many more are answered in this guide – I hope you enjoy it.

Don't miss tomorrow's guide in *The Sunday Telegraph* when we take a closer look at the science behind forecasting and the powerful forces at work that lead to extreme weather.



Siân Lloyd

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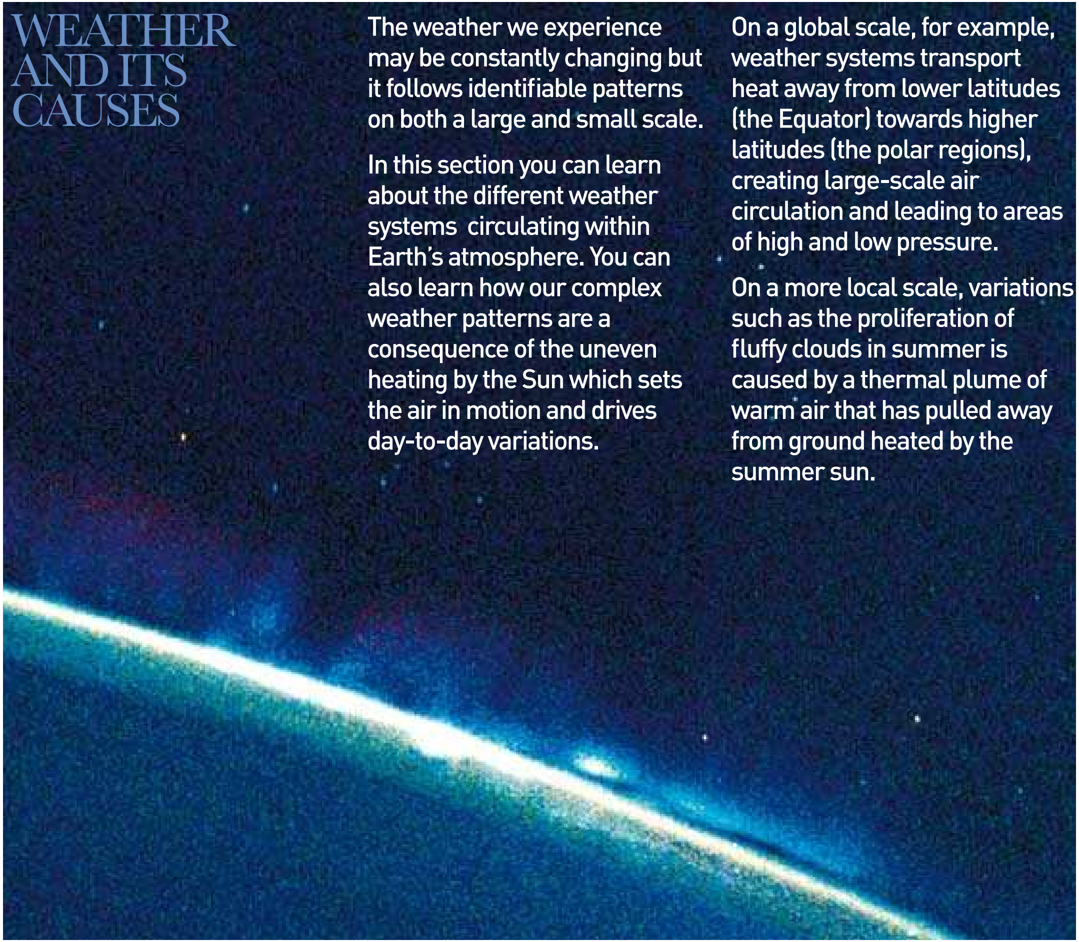


WEATHER AND ITS CAUSES

The weather we experience may be constantly changing but it follows identifiable patterns on both a large and small scale.

In this section you can learn about the different weather systems circulating within Earth's atmosphere. You can also learn how our complex weather patterns are a consequence of the uneven heating by the Sun which sets the air in motion and drives day-to-day variations.

On a global scale, for example, weather systems transport heat away from lower latitudes (the Equator) towards higher latitudes (the polar regions), creating large-scale air circulation and leading to areas of high and low pressure.

On a more local scale, variations such as the proliferation of fluffy clouds in summer is caused by a thermal plume of warm air that has pulled away from ground heated by the summer sun.

THE SOURCE OF ALL OUR ENERGY

The Sun provides the Earth with a near-constant supply of energy. It is this that makes life on Earth possible and drives our weather, from the seasons to what we expect day to day. Earth's weather patterns are ultimately determined by variations in the amount of this energy reaching different parts of the planet, caused by factors such as proximity to the Equator, pollution, and the reflectivity or absorbency of the land surface it falls on.

THE EARTH'S ATMOSPHERE

All weather occurs in the Earth's atmosphere, mostly in the lowest part – the troposphere. The atmosphere is a layer of gases surrounding the planet and held in place by gravity. It was created more than four billion years ago, and it has continued to evolve ever since. Its composition is changing rapidly in the present day due to the industrial activity of humans. It is believed that the earliest atmosphere was

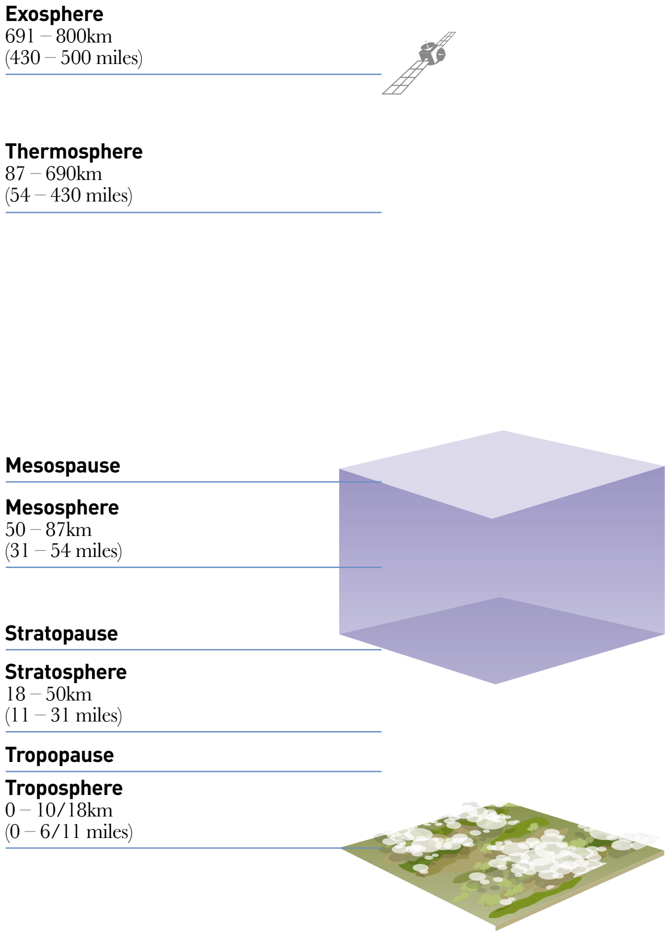
composed of hydrogen and helium. Today's atmosphere is principally composed of nitrogen and oxygen, with traces of argon, carbon dioxide, neon, methane, krypton and hydrogen, plus water vapour.

THE STRUCTURE OF THE ATMOSPHERE

Meteorologists split the atmosphere into different layers on the basis of how average temperature changes with height. The troposphere stretches from the Earth's surface up to about 10km (6 miles) at high latitudes and 18km (11 miles) at low latitudes. This layer contains all the weather systems and is characterised by falling temperatures, down to as low as -80°C (-112°F) at the top (the tropopause). Above this is the stratosphere, within which the temperature stays the same or increases with height due to the absorption of short-wave solar radiation by the ozone found at that altitude. The stratosphere is capped by the stratopause, where the temperature is around -10°C (14°F). Above this is the mesosphere, which absorbs little of the Sun's rays, and the temperature decreases with height up to the mesopause, around 87km (54 miles) up. This is the coldest part, where the air can be as cold as -90°C (-130°F). Above this is the thermosphere where temperatures can be raised as high as 15,000°C (27,000°F). The furthest layer is the exosphere, about 700km (430 miles) up.

ATMOSPHERIC LAYERS →

Temperature falls as you ascend through the troposphere, then rises through the stratosphere, falls through the mesosphere, and rises again through the thermosphere.



HEATING THE ATMOSPHERE

It isn't the Sun shining through our planet's atmosphere which gives us heat, it is the trace gases in the air such as carbon dioxide and water vapour that are central to warming Earth.

UNEVEN HEATING

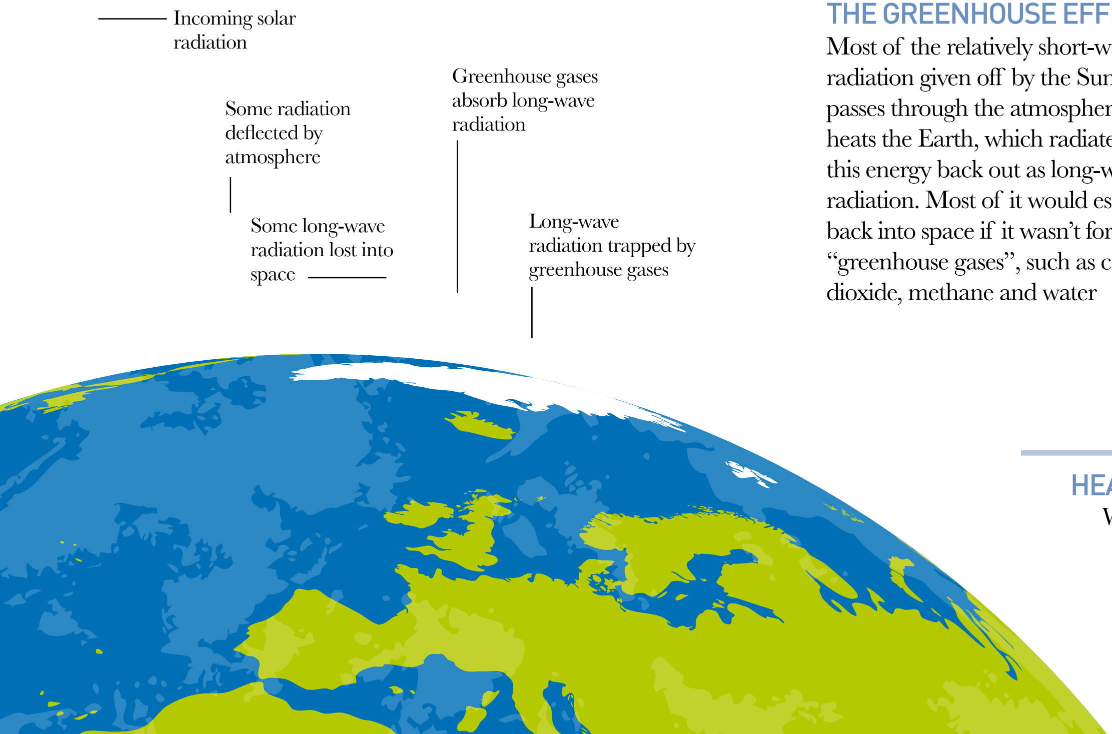
The incoming solar supply is concentrated most over the low, tropical latitudes and least across the higher polar regions of the globe. This is one reason why different temperature patterns are found throughout the world.

THE GREENHOUSE EFFECT

Most of the relatively short-wave radiation given off by the Sun passes through the atmosphere and heats the Earth, which radiates this energy back out as long-wave radiation. Most of it would escape back into space if it wasn't for the "greenhouse gases", such as carbon dioxide, methane and water vapour, which absorb a significant amount of the radiation flowing from the Earth's surface and the atmosphere to trap heat in – much like glass in a greenhouse. This effect is critical to life on the Earth. The surface is some 30°C (54°F) warmer than it would be without it.

BRIGHT AND DULL SURFACES

When the Sun's energy reaches the Earth's surface, some is absorbed and some is reflected. The proportion of radiation reflected depends on how bright a surface is (known as the surface's "albedo"). This varies from less than 10 per cent (a low albedo, meaning it absorbs more heat) for watery surfaces, to 90 per cent (a high albedo) for fresh snow.



HEATING UP

When radiation emitted by the Earth is absorbed by greenhouse gases, it is reflected back down, heating the surface of the Earth.

HOW ENERGY IS TRANSFERRED

All the Sun's energy flows as heat from one place to another in one of three different ways – radiation transfers heat by electromagnetic waves; convection by means of currents within a fluid, and conduction from one body to another through physical contact.

Nine paragliders at various heights floating on thermals in France

RADIATION

Radiation is given off by every body of matter in the universe and it is the only means of transferring energy that does not need a medium to transport it from one place to another. All the heat the Earth receives from the Sun travels through the near-vacuum of space as radiation and this radiation is the engine for all the Earth's weather.

CONVECTION

Convection is the process of transferring heat within a liquid or gas, like our atmosphere. Once the surface of the Earth has been heated by solar radiation, the warmth can be absorbed into the ground or transported up into the atmosphere as a "thermal", which lifts up and cools as it rises. Thermals are used by birds to help them ascend with minimum effort. Convection also transports warmth by evaporation. As the Sun warms the Earth, moisture at the surface evaporates. The resulting vapour is carried upwards in thermals. The air cools until it reaches a level where the water vapour in it starts to condense, resulting in the formation of clouds.

CONDUCTION

Conduction involves the transfer of heat by physical contact. Of the three modes of heat transfer, it is the least important to the atmosphere and weather because air is a very poor conductor. However, heat can be transferred by conduction to the lowest layer of the atmosphere by strong surface heating.

GLOBAL ENERGY TRANSFER

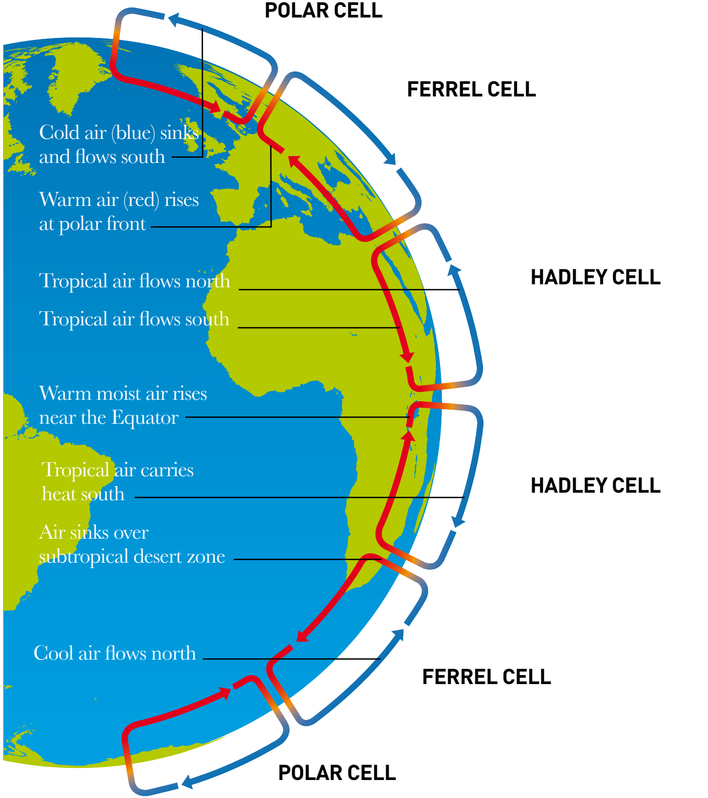
Air currents and water currents are caused by differences in temperature at the Earth's surface. Currents carry heat from low latitudes to high latitudes, cooling the tropics and warming mid and high latitudes.

THE TROPICAL BOILERHOUSE

The amount an area is warmed by the Sun equals the total incoming radiation minus the radiation that is reflected back into space. Regions that are often cloud-free, such as the subtropical oceans of the southern hemisphere, reflect little, and therefore have a large net solar radiation, while the ice sheets at the poles cause low values. This uneven energy distribution between the tropics and the poles produces a tropical "boilerhouse". Wind-driven surface ocean currents, such as the Gulf Stream, move warm water from this boilerhouse towards the poles. Cool water, such as the Canaries Current along the coast of north-west Africa, moves in the opposite direction. Deeper water is driven by variations in both temperature and salinity of the water. This is called the thermohaline circulation.

WINDY WINTER

The temperature difference between the tropics and polar regions in winter is roughly twice what it is in summer, largely because of the contrast between polar day and polar night. Winter winds over middle and high latitude oceans are stronger to meet the increased "demand" for heat transfer. This temperature difference is the reason weather tends to be more changeable in winter.



CIRCULATING CELLS The Hadley cells have the most regular pattern of air movement, and produce extreme wet weather at the Equator and extreme aridity in the deserts. The polar cells are the least well-defined.

GLOBAL CIRCULATION PATTERNS

The atmosphere contains several travelling weather systems with variable winds. When these winds are averaged over many years, both at the surface and at higher levels in the atmosphere, a well-defined pattern of large-scale "cells" of circulation appears.

GLOBAL CELLS

In each hemisphere there are three cells in which air circulates through the entire depth of the troposphere. The largest cells extend from the Equator to between 30 and 40 degrees north and south, and are named Hadley cells, after English meteorologist George Hadley. Within the Hadley cells, the trade winds blow towards the Equator over the low latitude oceans in either hemisphere, then ascend near the Equator as a broken line of thunderstorms, which form the Inter-Tropical Convergence Zone (ITCZ). From the tops of these storms, the air flows towards higher latitudes, where it sinks to produce the high-pressure regions over the subtropical oceans and the world's hot deserts.

In the middle cells, which are known as the Ferrel cells, air converges at low altitudes around 30 to 40 degrees north and south to ascend along the boundaries between cool polar air and the warm subtropical air that generally occurs between 60 and 70 degrees north and south. The circulation within this cell is completed by a return flow of air at high altitudes towards the tropics, where it joins the sinking air from the Hadley cell.

The smallest and weakest cells are the polar cells, which extend from between 60 and 70 degrees north and south, to the poles. Air in these cells sinks over the highest latitudes and flows out towards lower latitudes at the surface.

UPPER CIRCULATION AND JET STREAMS

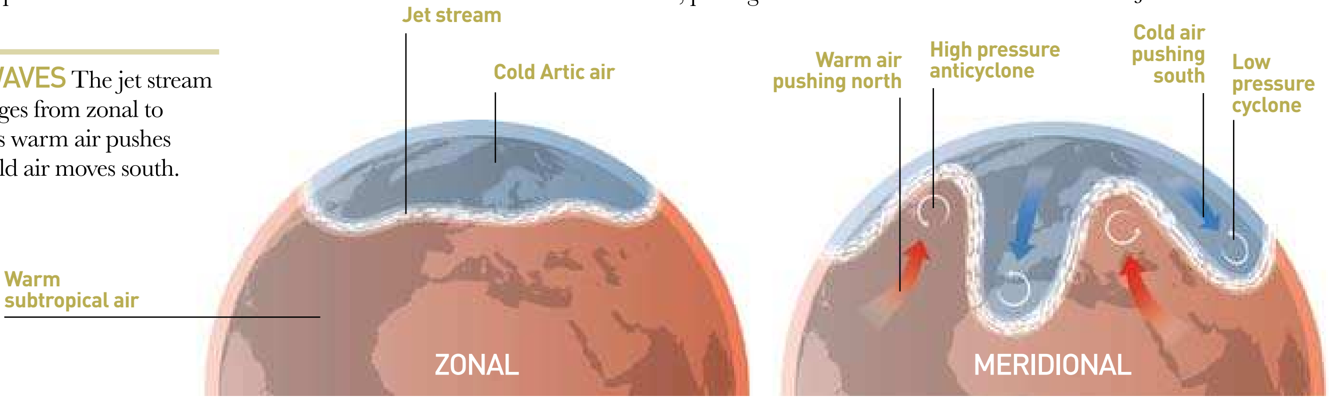
At low levels in the atmosphere, winds are slowed down by friction with the Earth's surface. Higher up, wind speeds can be much greater over a larger area, culminating in the mighty jet streams – fast-moving bands of air that blow around the globe at high altitude, reaching speeds of 280mph. There are four major jet streams – a polar-front jet stream and a subtropical jet stream in each hemisphere. They meander in wave-like paths around the world, which are constantly changing shape.

Jet streams have a big influence on global weather, creating highs and lows, which they then pull along with them. Large wave movements in the jet streams often signal extreme weather conditions, such as droughts and floods. Jet streams are produced when warm air meets and flows over much colder air in certain areas of the world. The greater the temperature difference, the faster the jet stream moves. This is why polar jet streams are more powerful than those in the subtropics.

THE JET STREAM AND UK WEATHER

The northern hemisphere polar jet, which here in the UK we generally refer to as "the jet stream" (even though it's just one of many), has the effect of guiding weather systems bearing rain and unsettled conditions across the Atlantic. This means it is the position of this jet stream that is important for UK weather as it can guide unsettled weather away from us, or right to our doorstep. During the summertime, we would normally expect the stream's location to be north of the UK, pulling those weather systems away and giving us more settled weather. In the winter, we would expect it to take a more southerly track, guiding those weather systems towards the UK to give us our typically unsettled winter weather. The jet stream does change track on a regular basis, however, which is why we can see periods of settled or unsettled weather at any time of year. Research is ongoing to understand how lots of different factors, such as changes in sea surface temperatures and reduced amounts of Arctic sea ice, can have an impact on the track and behaviour of the jet stream.

ROSSBY WAVES The jet stream pattern changes from zonal to meridional as warm air pushes north and cold air moves south.



AIR MASSES

Air masses – large bodies of air with a given temperature and humidity – are predominantly responsible for determining the broad type of weather we see here in the UK.

ARCTIC MARITIME AIR MASS
From: Arctic

POLAR MARITIME AIR MASS
From: Greenland/ Arctic Sea

POLAR CONTINENTAL AIR MASS
From: Central Europe

RETURNING POLAR MARITIME
From: Greenland/ Arctic via north Atlantic

TROPICAL MARITIME AIR MASS
From: Atlantic

TROPICAL CONTINENTAL AIR MASS
From: North Africa

THE DYNAMICS OF AIR MASSES

Air masses are classified as continental or maritime – depending on whether they originate over land or sea – and in the UK as arctic, tropical or polar, depending on the particular region in which they are formed. They are created when a large volume of air remains over a surface for a prolonged period and takes on the climatic qualities of that surface. Air masses extend far into the troposphere and can cover millions of square kilometres.

UK AIR MASSES

Tropical maritime (Tm)

This comes from warm waters of the Atlantic, brought in on a south-westerly wind. Tropical maritime air is warm and moist, and usually stable – bringing mild conditions with low cloud and drizzle, and perhaps also fog.

Returning polar maritime (rPm)

A variation of polar maritime, this originates over Greenland and northern Canada but has a much longer track over the Atlantic, first heading southwards before returning to the UK. Brings mainly dry weather with extensive stratocumulus cloud.

Polar maritime (Pm)

Common over the UK, this air mass originates over northern Canada and Greenland and reaches the British Isles on a north-westerly air stream. It is unstable, bringing frequent showers, or even hail and thunder.

Arctic maritime (Am)

This has similar characteristics to a polar maritime, but the air is colder and less moist. In summer it can bring heavy showers and low temperatures. In winter the air is cold enough to produce hail or snow.

Polar continental (Pc)

A winter air mass originating from the snow fields of Eastern Europe, blown in on easterly winds. It is inherently very cold and dry, but can bring rain or snow if it has a long track over the North Sea.

Tropical continental (Tc)

Most common in summer months, these originate from North Africa and are brought to the UK by south-easterly winds. They bring warm conditions – and often reduced visibility, as the air picks up pollutants as it passes over Europe.

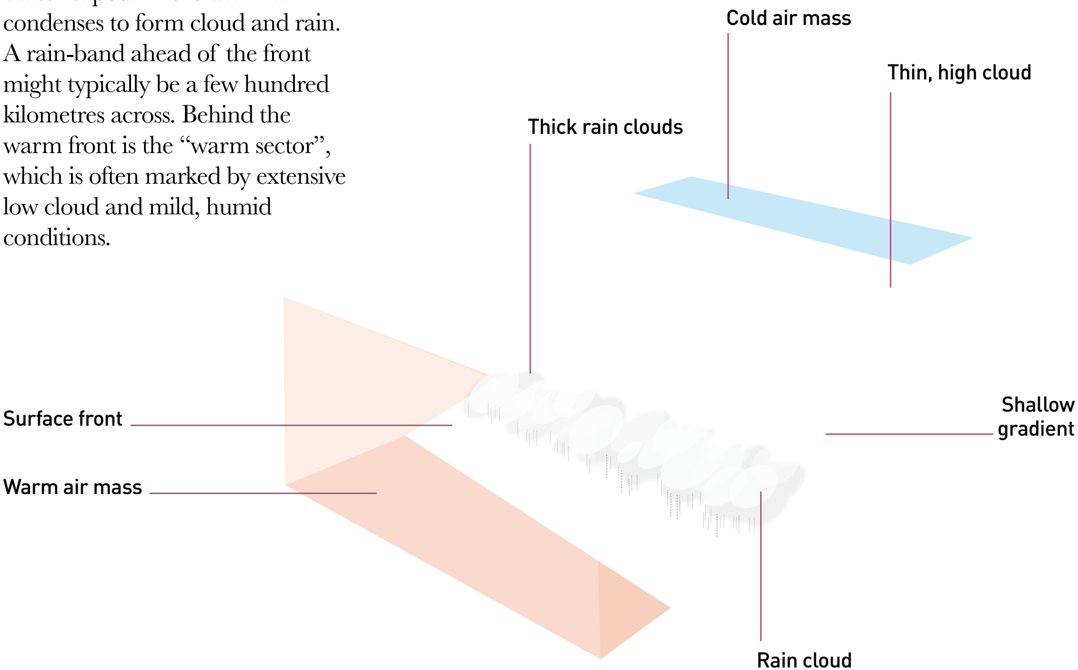
WEATHER FRONTS

Fronts are areas where two air masses of differing temperature and density meet. Whether warm, cold or occluded, these moving weather systems bring much of the rain to the UK.

WARM FRONTS

A warm front occurs at the leading edge of warm, moist, tropical air that replaces cooler air as it moves. The warm air slides up over the cooler air to form a warm front with a shallow slope. Water vapour in the warm air condenses to form cloud and rain. A rain-band ahead of the front might typically be a few hundred kilometres across. Behind the warm front is the "warm sector", which is often marked by extensive low cloud and mild, humid conditions.

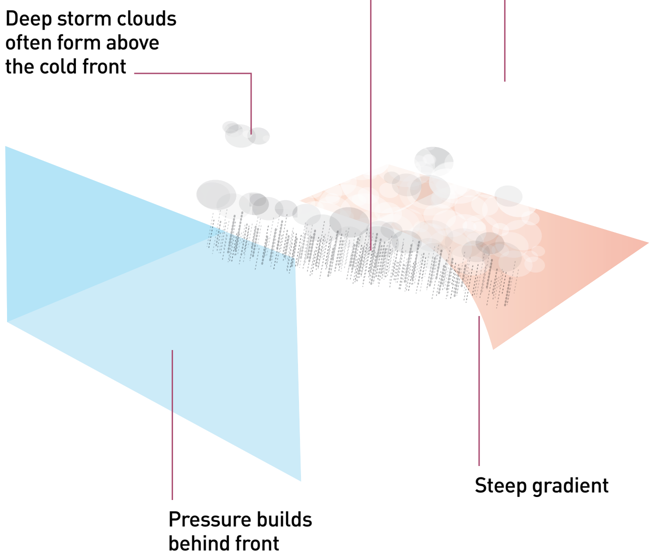
A rain-band ahead of the surface front may be a few hundred kilometres across. The front is followed by a warm sector with mild, humid air.



COLD FRONTS

A cold front occurs at the leading edge of a sweep of much cooler and drier air. The cooler, denser air will push under the warm air to form a cold front with a steep slope. This often brings a band of cumulus-type clouds which can bring heavy but short-lived rain. This is followed by a drop in temperature and humidity, clear skies and high visibility.

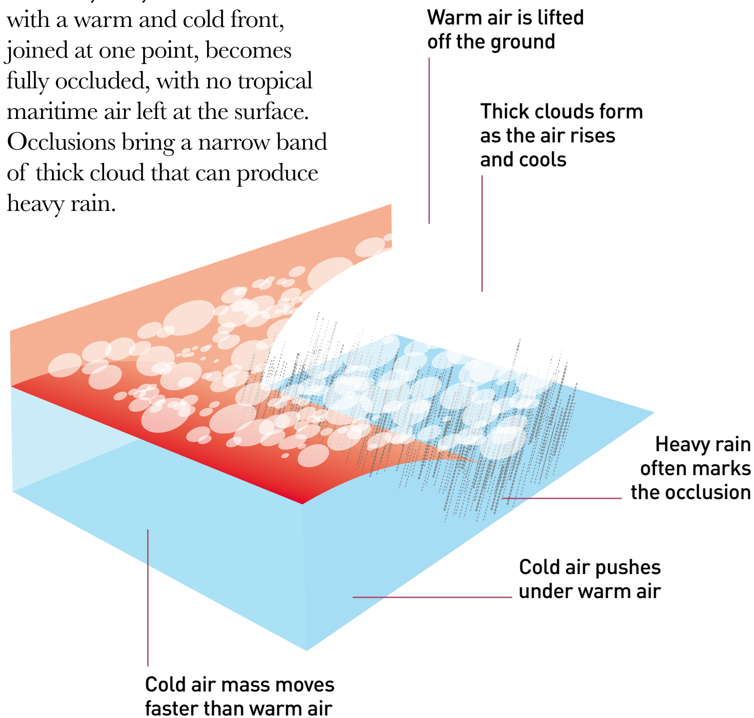
The heavy but short-lived and sometimes thundery rain produced by a passing cold front is followed by a drop in temperature and humidity as fresher air replaces the warm sector air.



OCCLUDED FRONTS

Cold fronts travel faster than warm fronts. A cold front can catch up with a warm front and push underneath it, lifting the warm air off the ground. This process is continuous, so that after a few days a system that started with a warm and cold front, joined at one point, becomes fully occluded, with no tropical maritime air left at the surface. Occlusions bring a narrow band of thick cloud that can produce heavy rain.

The warmer air is forced upwards by the cold air of the cold front. The rising warm air produces increased cloud and rain.



HIGHS AND LOWS

Highs and lows are pressure systems that cause the day-to-day changes in the weather. High pressure areas occur where a large mass of air is sinking, and low pressure areas where the air is rising. The air moving from areas of high pressure to areas of low pressure is the wind we feel.

PRESSURE

Pressure is measured in hectoPascals (hPa), also called millibars. Standard pressure at sea level is defined as 1013hPa, but we can see big areas of either low or high pressure. These are all relative to each other – so what constitutes a high will change depending on the area around it.

HIGH PRESSURE

Highs (also known as anticyclones) are extensive regions, perhaps a few thousand kilometres across, in which there is a large amount of air in the "column" stretching from surface-level to the edge of the atmosphere. Air descends slowly in these columns, then moves outwards as wind at low altitudes.

LOW PRESSURE

Lows (also known as cyclones) tend to be more compact than highs and contain a smaller mass of air which rises. The air cools as it rises, allowing water vapour to condense, creating clouds which can lead to precipitation – rain, hail or snow.

WINDS

As the atmosphere is constantly trying to even out imbalances, air rushes from areas of high pressure to areas of low pressure – creating wind. Due to the Coriolis effect (see right), it does not take a direct route, instead it circulates in ever-decreasing circles to the centre of the low. The greater the difference between pressures (the pressure gradient), the stronger the wind. Areas of high and low pressure are always being created, making this evening-out process a constant in the global atmosphere.

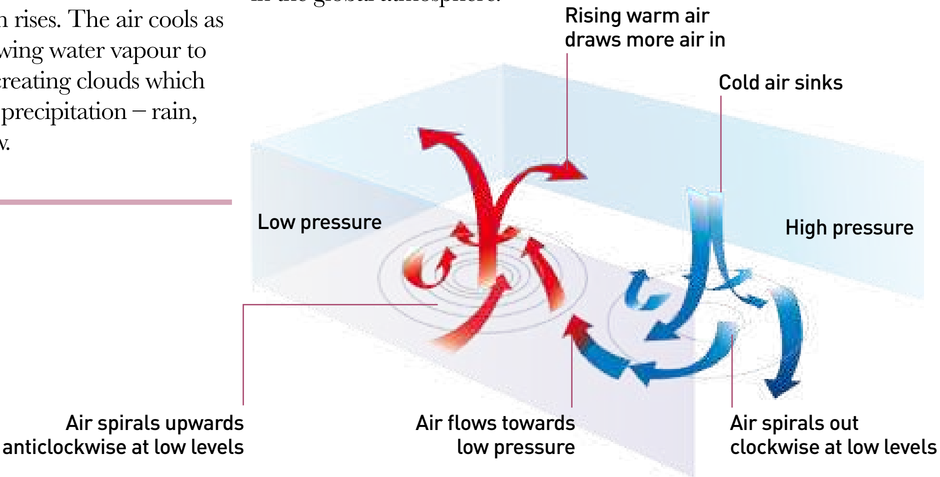
The Coriolis effect

Because of the Earth's rotation, we experience an apparent force known as the Coriolis effect. The direction of the wind is deflected to the right in the northern hemisphere and to the left in the southern hemisphere.

Buys-Ballot's Law

If you stand with your back to the wind in an open area in the northern hemisphere, low pressure will be on your left and high pressure will be on your right.

AIR FLOW In the northern hemisphere, air sinks in an area of high pressure in a clockwise spiral, then flows towards the low pressure to rise in an anticlockwise spiral. In the southern hemisphere, it sinks anticlockwise and rises clockwise.



INTRODUCING CLOUDS

Without clouds life on Earth would not exist. They are instrumental in regulating the climate by reflecting solar radiation and absorbing outgoing radiation. Clouds form when water vapour in moist, rising air condenses, resulting in precipitation – rain, hail, sleet and snow.

CLOUD FORMS

The Earth's surface climate is tempered by cloud. Without clouds, the difference between day and night temperatures can be very large. Clouds also play a critical role in determining the radiation balance of the Earth and its atmosphere. The shape of a cloud reflects the way in which moist air has risen to allow it to develop. Some of the smallest clouds are fair-weather cumulus, a type of bulbous "cauliflower" type cloud that is created by thermals that rise above the Earth's surface and cool to such a degree that condensation occurs. This happens on a horizontal scale of hundreds of metres.

On the largest scale, deep, precipitating layer clouds form within the very extensive but gentle rising air that is part of the circulation of frontal depressions. Many thousands of square kilometres of tropical maritime air mass is forced to rise to produce the distinctive, large comma shape of these disturbances.

Condensation is not only forced by upward motion within the atmosphere but can often be produced by moist air flowing over hills and mountains, causing orographic clouds to develop.

CLOUD CLASSIFICATION

The system for classifying clouds uses four Latin terms: stratus, cumulus, nimbus and cirrus. Some are combined, so that nimbostratus, for example, is a layer of raincloud. Clouds are also classified as high, middle or low, according to the height of the cloud base above the surface.

NAMES FOR CLOUDS

The names for clouds are usually combinations of the following prefixes or suffixes:

Stratus/strato: flat/layered and smooth

Cumulus/cumulo: heaped up/puffy, like cauliflower

Cirrus/cirro: High up/wispy

Alto: Medium level

Nimbus/Nimbo: Rain-bearing cloud

HOW CLOUDS FORM

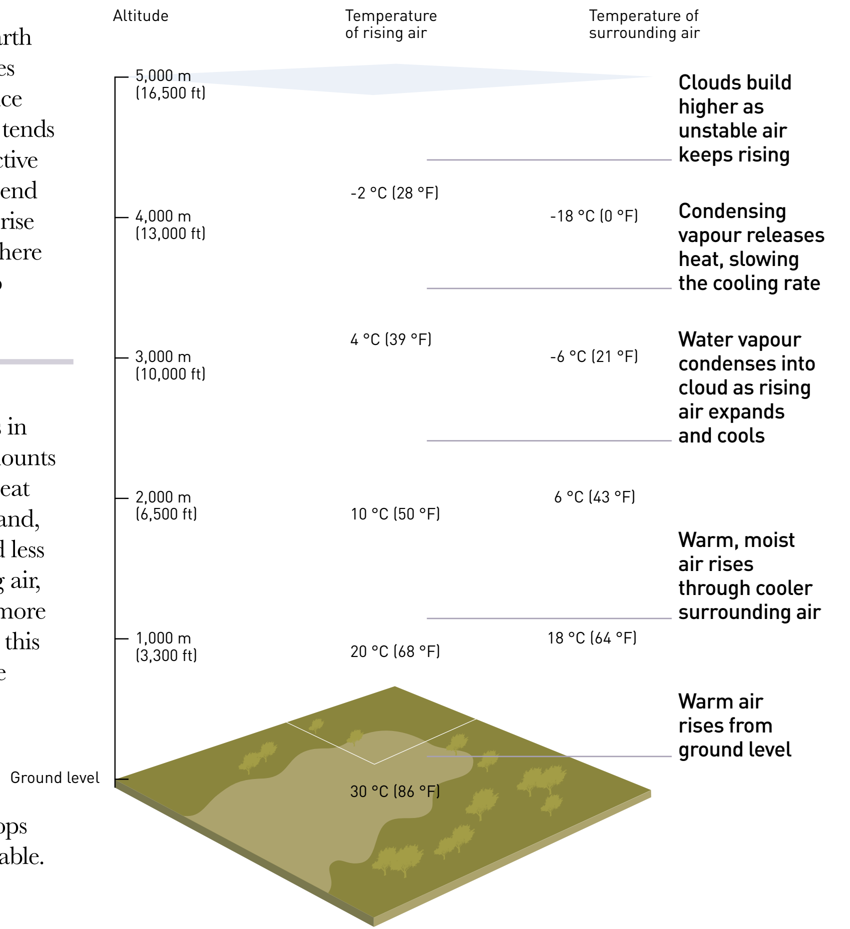
The shape and appearance of a cloud reflects how the air has risen to form it – from expansive areas of stratus created by the slow ascent of air into depressions, to individual cumulus clouds produced by strong, localised thermals.

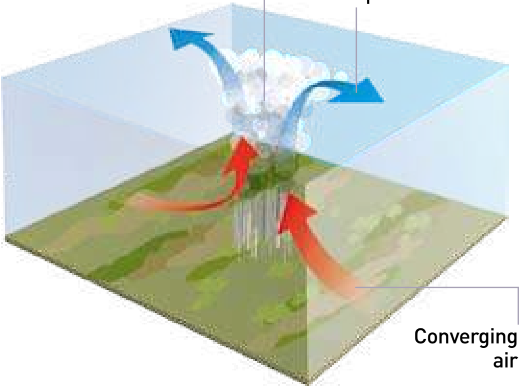
SURFACE HEATING

When the surface of the Earth is heated by the Sun, air rises in thermals that may produce cloud. This surface heating tends to produce scattered convective cloud. If these thermals ascend in a cold air mass, they will rise further through the atmosphere and may go high enough to form a shower cloud.

UNSTABLE AIR

As water vapour condenses in rising, cooling air, small amounts of heat are released. The heat warms the air mass a little and, if this makes it warmer and less dense than the surrounding air, air rises further. If there is more water vapour left in the air, this too condenses and the cycle continues. This rising air is known as unstable air.
If it reaches the same temperature and density as the surrounding air, it stops rising and is described as stable.



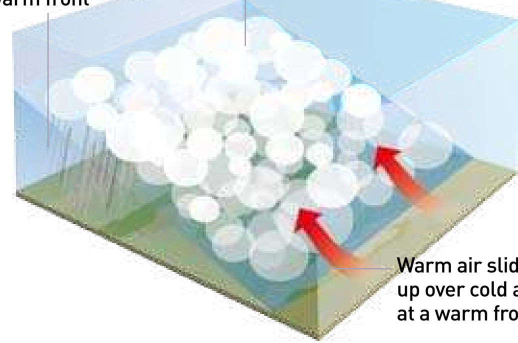


LOW-LEVEL CONVERGENCE

The air at low levels in the atmosphere may flow towards, or converge on, a line or centre of circulation. The scale of this convergence can vary from a large depression across hundreds of kilometres to a more localised area just tens of kilometres in size. Clouds formed in this way can range from fluffy cumulus clouds that deliver short showers to large thunderstorms.

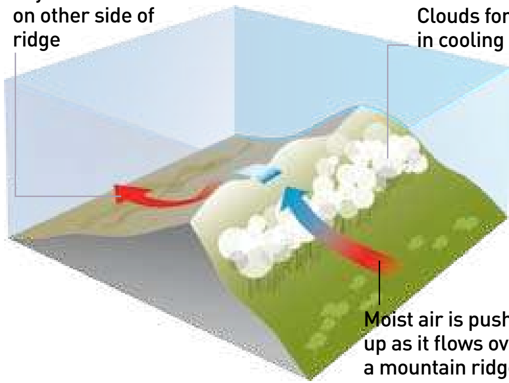
FRONTAL UPLIFT

Rising air on a much larger scale occurs along fronts, the long boundaries that separate warm, moist subtropical air from much cooler, drier air from higher latitudes. Widespread and often deep layers of cloud are formed when the warmer air is forced to ascend over a wedge of the drier, cooler, undercutting air. Frontal clouds can stretch for more than a thousand kilometres.



OROGRAPHIC FORCING

As air rises up over hills or mountains, it can cool to form clouds above the summit. These may dissipate in the wind or dissolve as they flow down the other side of the mountain into warmer drier air. Because new cloud keeps forming at the summit, however, these clouds can have the appearance of a “cap” of cloud on top of the raised area. Conditions will generally be rainy on the slopes facing the wind and dry on slopes facing away.



LOW-LEVEL CLOUDS

Stratus clouds are the lowest lying clouds, forming either a continuous layer or ragged shreds just above the ground.

St

STRATUS

Altitude: Bases form between the surface and 2,000m (6,500ft) above the ground

Shape: Horizontal, layered clouds

Precipitation: Very light

Most stratus clouds are featureless, low-altitude clouds that cover the sky in a blanket of grey or white. The cloud layer can be thick enough to completely block out the Sun or Moon and may produce drizzle, snow, or snow grains. Stratus clouds develop in several different ways. Upslope stratus clouds form when moist air is lifted up by the wind as it blows against a cliff, hill or mountain. Stratus clouds can also develop over the sea, when relatively warm, moist air over the water condenses as it cools. During the summer, sea breezes may blow stratus clouds onto the coast, resulting in lower air temperatures for these regions. Wherever stratus clouds touch the ground or meet the sea, they are classed as fog. This fog may lift due to an increase in the strength of the wind or a rise in temperature and form stratus clouds again. Different types of stratus clouds include stratus nebulosus, stratus fractus, and stratocumulus.

St neb

STRATUS NEBULOSUS

Altitude: Bases form between the surface and 450m (1,500ft) above the ground

Shape: Featureless cloud blanket

Precipitation: Very light

Stratus nebulosus is the most common type of stratus cloud, usually bringing dull, grey weather. Generally, the only precipitation to fall from stratus nebulosus clouds is drizzle.

St fra

STRATUS FRACTUS

Altitude: Bases form between the surface and 450m (1,500ft) above the ground

Shape: Ragged and tufted

Precipitation: Very light

These ragged shreds of low cloud normally appear in association with other clouds, especially with precipitation or soon after it has stopped, often forming beneath altostratus or nimbostratus. Stratus fractus clouds also occur beneath cumulonimbus and cumulus clouds, when they are collectively known as stratus pannus. Stratus clouds appear dark or grey against the lighter grey of the clouds above and move quickly across the sky, changing shape rapidly.

Sc

STRATOCUMULUS

Altitude: Height of base 350-2,000m (1,200-6,500ft)

Shape: Cumuliform “lump” at base

Precipitation: Light

Stratocumulus clouds consist of large, rounded masses that form groups, lines or waves. The clouds are grey or white, usually with darker parts. Stratocumulus clouds can appear in many weather conditions. During dry, settled weather, the clouds may be dominant and persistent. Stratocumulus clouds are usually present during a warm, cold or occluded front. They can be thick enough to produce light rain or snow.

Cu

CUMULUS

Altitude: Height of base 400-2,000m (1,200-6,500ft)

Shape: Cauliflower or fluffy in appearance

Precipitation: Occasional rain or snow showers

All cumulus clouds develop because of convection. As air heated at the surface is lifted, it cools and water vapour condenses to produce the cloud. Near coasts, cumulus may form over the land by day as a sea breeze brings in moist air, which is then warmed by the land, and over the sea during the night when a breeze blows off the land over the sea, which is now warmer than the land. These clouds can often provide a spectacular sight in the sky. Certain types of cumulus cloud are typical of showery conditions and may even produce thunderstorms.

Cu hum

CUMULUS HUMULIS

Altitude: Usually 400-2,000m (1,200-6,500ft)

Shape: Detached with ragged tops

Precipitation: None

On clear mornings, especially during the summer, this type of cloud may form as the Sun quickly warms the ground. Stratus may lift and develop into cumulus humulis. When completely formed, the clouds have clear-cut horizontal bases and flattened, or slightly rounded, tops. At this stage they are known as fair-weather cumulus.

Cu med

CUMULUS MEDIOCRIS

Altitude: Usually 400-2,000m (1,200-6,500ft)

Shape: Individual and heaped

Precipitation: Occasional showers

These clouds develop from cumulus humulis. Their outline is usually more defined, with horizontal bases and cauliflower-shaped tops. Sunlit parts of the cloud can become brilliant white, while bases are relatively dark.

The clouds are sometimes arranged in lines, called cloud streets, parallel to the wind direction. They may also form with tall towers that are tilted by the wind. When well developed, cumulus mediocris clouds sometimes produce showers. Whatever their stage of development, cumulus clouds usually disperse in the late afternoon or early evening over land. Over oceans, maximum cumulus activity occurs in the late hours of the night.

Cb

CUMULONIMBUS

Altitude: Height of base 350-2,000m (1,200-6,500ft)

Shape: Fibrous upper edges, anvil top

Precipitation: Heavy rain and thunderstorms

Cumulonimbus clouds usually form after the Sun has heated the sea or land for several hours, causing warm air to rise, cool and condense. If the weather conditions are right, a mature cumulus congestus cloud will grow in height and become a cumulonimbus. As this happens, water droplets begin to freeze and the appearance of the upper cloud portion alters and becomes wispy. New cloud development may temporarily give a cumulonimbus the appearance of a "towering" cumulus. When this happens, lightning, thunder or hail are sometimes the only indication that the cloud is a cumulonimbus. This may also be the case when a cumulonimbus passes nearly or directly overhead and the characteristic top is lost to view. With only the base visible, it is easy to mistake the cloud for a nimbostratus, but lightning, thunder, hail or other precipitation show that it is a cumulonimbus cloud. The characteristic shape of these enormous clouds can only be seen as a whole when viewed from a distance, where the tops reveal a fibrous or striated structure that often resembles an anvil or plume. Rain or snow is often seen falling from a cumulonimbus cloud, either at a distance or close-up. A variety of other clouds may be present at the same time as a cumulonimbus.

MEDIUM-LEVEL CLOUDS

Altocumulus, often with layered or rippled elements, is the most distinctive of all the medium-level clouds – other types can be relatively featureless.

Ac

SEMI-TRANSPARENT ALTOCUMULUS

Altitude: Height of base 2,000-5,5000m (7,000-18,000ft)

Shape: Bands or areas of individual cells

Precipitation: None on its own

This type of cloud produces a "mackerel sky". It resembles stratocumulus, but has a higher base. Semi-transparent altocumulus appears at a single level, the greater part of which is sufficiently transparent to reveal the position of the Sun or Moon, and may produce a corona – a small halo effect around the Sun or Moon. These clouds are generally associated with settled weather. The clouds usually appear white or grey with shading, although the dawn or dusk sunlight can produce a spectacular yellow or orange effect.

Ac cast

ALTOCUMULUS CASTELLANUS

Altitude: Height of base 2,000-5,5000m (7,000-18,000ft)

Shape: Turret-like features

Precipitation: Possible precursor to thunderstorm

Altocumulus castellanus, also called thundery altocumulus, is a sign of medium-level instability. The clouds normally appear in the form of small individual cells with sproutings in the form of small towers. If conditions are cool and moist enough, they can develop into large cumulonimbus and produce thunderstorms.

Ac

ALTOCUMULUS OF A CHAOTIC SKY

Altitude: Height of base 2,000-5,5000m (7,000-18,000ft)

Shape: More than one layered band

Precipitation: Possible showers

A chaotic sky with many layers of different clouds means that weather is arriving from many different directions. Altocumulus of a chaotic sky generally occurs at several levels with the different cloud bases ranging in height widely at any one time. More than one type of altocumulus can normally be observed at the same time. The cloud sheets are often broken, with poorly defined cloud types. There is usually a mixture of low- and high-level clouds in this type of sky, usually associated with changeable weather.

As

ALTOSTRATUS

Altitude: Height of base 2,000-5,500m (7,000-18,000ft)

Shape: Layered and featureless

Precipitation: None

Altostratus evolves as a thin layer from a gradually thickening veil of cirrostratus. Thin altostratus normally has a higher base than the dense variety, at 4,000–5,500m (14,000-18,000ft). Thin altostratus is usually grey or blue in colour. An important aspect when identifying the cloud is to look for shadows cast on the ground. Although it may still be bright during the day, thin altostratus will be thick enough to prevent shadows appearing. Much of the cloud will be translucent enough to see the Sun or Moon, as if through ground glass.

Ns

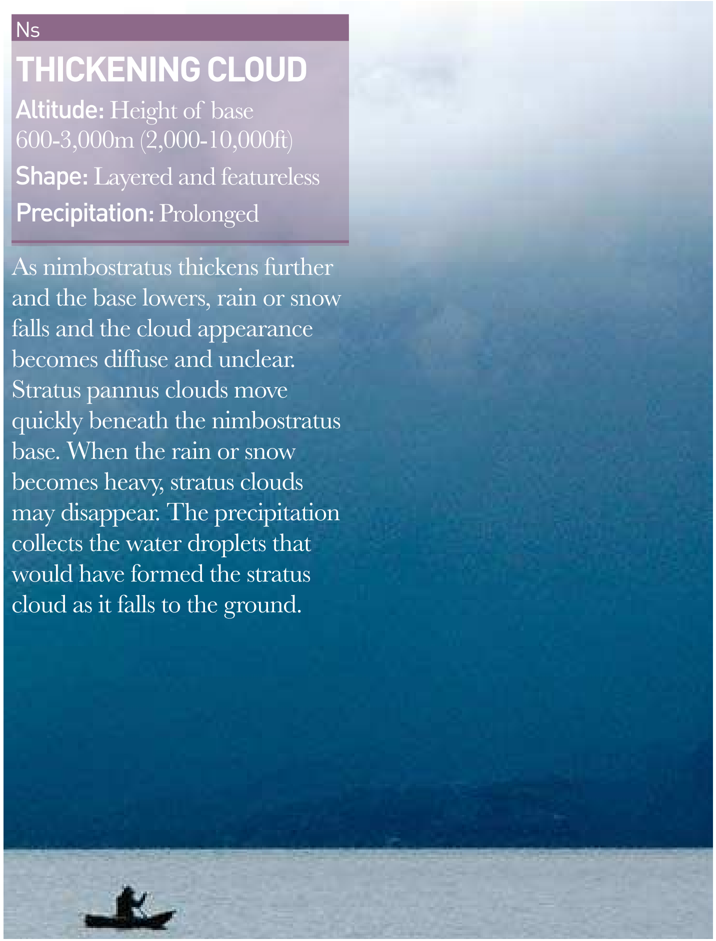
NIMBOSTRATUS

Altitude: Height of base 600-3,000m (2,000-10,000ft)

Shape: Layered and featureless

Precipitation: Continuous rain or snow likely

When altostratus continues to thicken, this is usually a good indicator that a weather front is nearing and the chance of rain or snow is increasing. Eventually it can thicken into the rain-giving nimbostratus cloud. Nimbostratus is a darker grey or more bluish grey than the thinner altostratus from which it often develops. The layer of cloud will cover much – if not all – of the sky, and the greater part of the cloud will be thick enough to hide the Sun or Moon. Where there is a dense covering of altostratus or nimbostratus, ragged shreds of stratus clouds are often present. Once precipitation begins to fall, it may last for several hours until the front passes over.



Ns

THICKENING CLOUD

Altitude: Height of base 600-3,000m (2,000-10,000ft)

Shape: Layered and featureless

Precipitation: Prolonged

As nimbostratus thickens further and the base lowers, rain or snow falls and the cloud appearance becomes diffuse and unclear. Stratus pannus clouds move quickly beneath the nimbostratus base. When the rain or snow becomes heavy, stratus clouds may disappear. The precipitation collects the water droplets that would have formed the stratus cloud as it falls to the ground.

HIGH-LEVEL CLOUDS

Because of their high altitude, cirrus, cirrostratus, and cirrocumulus clouds consist entirely of ice crystals. These wispy clouds drift across the upper part of the troposphere and can be an indication of local wind patterns.

Ci

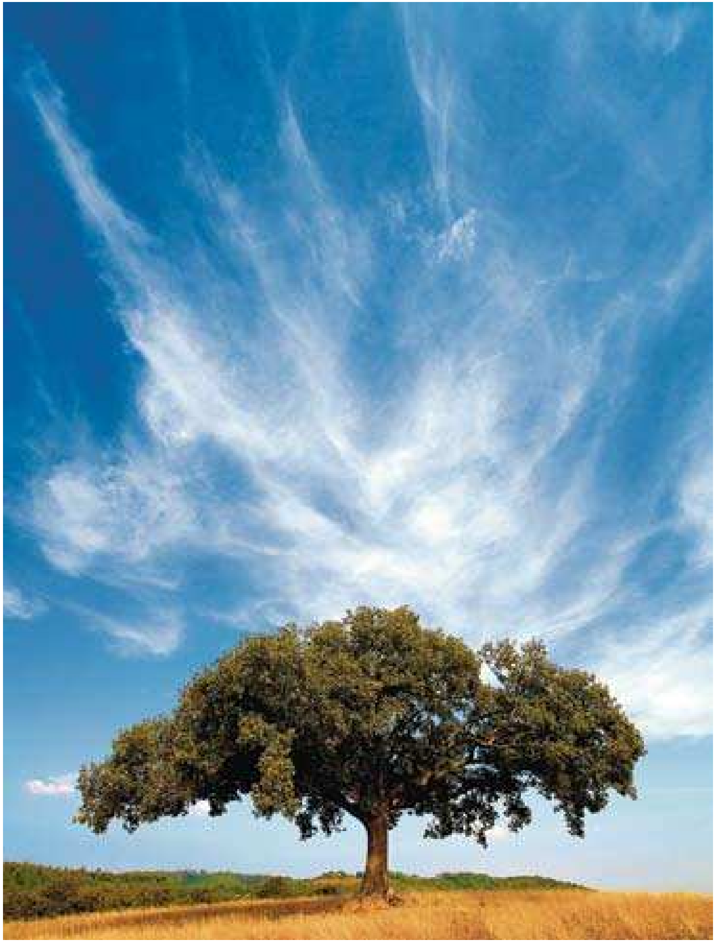
CIRRUS

Altitude: Height of base 5,500-12,000m (18,000-40,000ft)

Shape: Layered, tufted or patchy

Precipitation: None

All high-level clouds are derivatives of cirrus clouds. They can be seen at any time of the year and, because they are made of ice crystals, they are usually white. They form a wide range of shapes and sizes throughout the year and may be a good indicator of the type of weather to expect in the coming hours. Frequently, cirrus clouds form dense shelves, which sometimes appear entangled. They also form thick patches that may be dense enough to obscure the Sun. Cirrus clouds in narrow bands or turrets are called cirrus castellanus. Those with a more ragged shape are known as cirrus floccus.



Ci

MARES' TAILS

Altitude: Height of base 6,000-12,000m (20,000-40,000ft)

Shape: Hair-like tufts or hooks

Precipitation: None

Cirrus clouds that are shaped like commas and topped with a hook or a tuft are often called "mares' tails". Overall, these cirrus clouds may form a structure that looks like a fish skeleton, with a thick "spine" and filaments on either side. Mares' tails sometimes occur at the same time as other cirrus clouds, but on their own they are usually seen during a spell of fine, settled weather.

Cc

CIRROCUMULUS

Altitude: Height of base 6,000-12,000m (20,000-40,000ft)

Shape: Layers or patches of cells

Precipitation: None

Cirrocumulus clouds are relatively rare. They have no shading and often form ripples, which may resemble honeycomb. These clouds sometimes appear in waves and are known as a "mackerel sky" (some altocumulus clouds also appear in this pattern and can be mistaken for cirrocumulus). Cirrocumulus clouds form when cirrus or cirrostratus clouds are warmed from below, causing the air to rise and sink. Some ice crystals turn into water vapour, causing gaps to appear in the clouds.

Cs

CIRROSTRATUS

Altitude: Height of base 5,500-12,000m (18,000-40,000ft)

Shape: Layered

Precipitation: None

This thin, layered cloud is composed of ice crystals, and forms a veil that covers part, or all of the sky. Cirrostratus cloud is often the forerunner to an approaching front and can herald unsettled, wet weather. The relationship between cirrostratus and changes in the weather makes correct identification very important. Near the horizon, cirrostratus is often mistaken for altostratus, but the slow speed at which it moves and changes is a good indicator that it is cirrostratus. As it continues to invade the sky, cirrostratus usually grows thicker, although small cumulus clouds may develop. Where cirrostratus does not spread across the whole of the sky, the visible edges may be sharp but are mostly irregular.

OROGRAPHIC AND SPECIAL CLOUDS

Rare cloud phenomena such as orographic cloud develops on a local scale as a result of geographic features like hills and mountains. Even rarer clouds such as nacreous develop in the lower stratosphere – well above the altitude where the weather affecting us is formed.

LENTICULAR CLOUD

Altitude: 2,000-5,000m (6,500-16,500ft)

Shape: Lens-shaped

Precipitation: Possible light rain or snow

These orographic wave clouds form when, in stable air, the wind blows from the same or similar direction at many levels of the troposphere. As the wind blows across regions of hills and mountains, the air undulates in a downstream train of waves.
If there is sufficient moisture in it, the air rising on the crest of a wave will condense into a cloud. These clouds can be seen over 100km (60 miles) downwind of the hills or mountains that have triggered them.

KELVIN-HELMHOLTZ CLOUD

Altitude: Above 5,000m (16,500ft)

Shape: Regular waves of cirrus cloud

Precipitation: None

Kelvin-Helmholtz or billow clouds are rare and occur when there is a strong vertical wind shear between two air-streams. The wave pattern is produced when the wind blows faster at the upper level than at lower levels. The phenomenon is named after Hermann von Helmholtz and William Thomson Kelvin, scientists who studied turbulent air-flow.

BANNER CLOUD

Altitude: Mountain tops

Shape: Layered

Precipitation: None

Banner cloud is caused by the uplifting of the air. When the wind blows against a hill or mountain, it is forced to lift. As it rises, the air cools and water vapour in it condenses to produce a cloud. Banner clouds form in a layer and then remain almost stationary, as the wind continuously blows in from one direction.

NACREOUS CLOUD

Altitude: 21-30km (13-19 miles)

Shape: Thin layer

Precipitation: None

Nacreous clouds form in the lower stratosphere over polar regions and have the appearance of pale cirrus or lenticular altocumulus. When the Sun is just below the horizon and illuminates the clouds from below, they may glow in vivid colours. The clouds can still be distinguished a couple of hours after sunset, when they look like thin grey clouds, and may remain visible by moonlight through the night. Nacreous clouds form at below -78ºC (-109ºF), temperatures that occur in the lower stratosphere during the polar winter.

NOCTILUCENT CLOUD

Altitude: 72-90km (45-56 miles)

Shape: Layered and tufted

Precipitation: None

It is still not known how these extremely rare clouds form. Noctilucent clouds have mainly been observed during clear midsummer nights at the latitudes of 55-65 degrees, but only in the northern hemisphere. They closely resemble thin cirrus in shape, but are normally bluish or silvery in colour, sometimes appearing orange or red when close to the horizon. The clouds begin to appear at the same time as the brightest stars but are more brilliant after midnight.

INTRODUCING PRECIPITATION

Precipitation – whether it falls as rain, snow, or hail – can range from minute drops of drizzle to enormous frozen hailstones in an intense, short-lived, and localised burst.

RAINDROPS

Water warmed by the Sun evaporates into rising vapour. If the air cools sufficiently, the vapour may condense around dust or other microscopic particles called "condensation nuclei". Minute droplets of liquid water then become visible as a cloud. Droplets fall through the cloud and may combine into raindrops on their way down. The raindrops fall to the ground once they become too heavy to be supported by the updraughts that created the cloud.

FROZEN PRECIPITATION

Cloud droplets can remain liquid at temperatures well below freezing in a "supercooled" state, and all droplets become ice crystals only at, or below about -40°C (-40°F). Snowflakes form when supercooled droplets freeze onto ice crystals. This is called "accretion". Ice crystals stick to other crystals by "aggregation" to form larger flakes. Snowflakes may melt and reach the ground as rain. If the air temperature is low enough, snow will reach the ground.

Hailstones are formed in storm clouds when ice crystals from high in the cloud fall to a lower level but are thrown up again by powerful updraughts, collecting layers of ice by aggregation, before finally falling to the ground.

RAIN

Rain is classified according to how it is generated, whether it is by an approaching front, convective cloud, or by a cyclone, and can vary in size from 0.5mm (1⁄50in) to 6mm (1⁄5in) across.

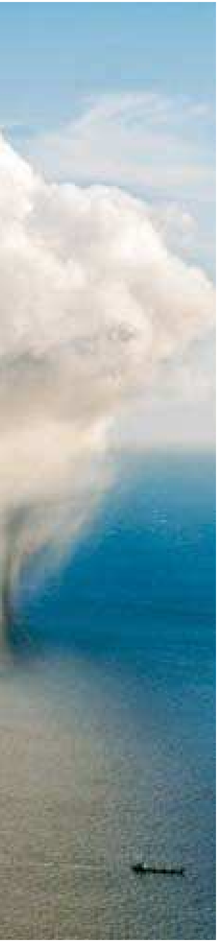
CONVECTIVE RAIN

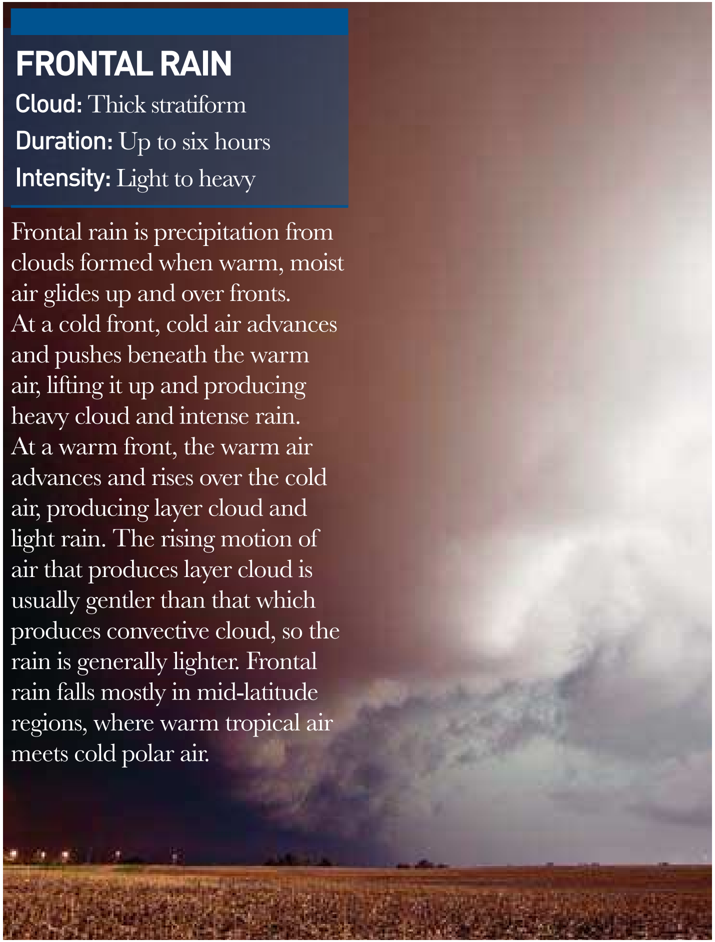
Cloud: Tall cumuliform

Duration: Showery, generally an hour or less

Intensity: Light to intense

Convective rain falls from cumuliform clouds. Its intensity and duration varies depending on cloud size. Raindrops can grow to their maximum size – about 6mm (1⁄5in). Convective rain is "showery", meaning that it is usually short-lived and relatively intense. Slow-moving vigorous convective storms, producing cumulonimbus clouds, and thunderstorms, can produce very large amounts of rainfall.





FRONTAL RAIN

Cloud: Thick stratiform

Duration: Up to six hours

Intensity: Light to heavy

Frontal rain is precipitation from clouds formed when warm, moist air glides up and over fronts. At a cold front, cold air advances and pushes beneath the warm air, lifting it up and producing heavy cloud and intense rain. At a warm front, the warm air advances and rises over the cold air, producing layer cloud and light rain. The rising motion of air that produces layer cloud is usually gentler than that which produces convective cloud, so the rain is generally lighter. Frontal rain falls mostly in mid-latitude regions, where warm tropical air meets cold polar air.

OROGRAPHIC RAIN

Cloud: Thick stratiform

Duration: Up to 12 hours

Intensity: Light to heavy

As an air mass blows from the sea over hilly land, the damp air rises and condenses. Cloud produced in response to the topography of the land in this way is called orographic cloud. Above the orographic cloud is a rain cloud that has formed over the sea, called a "seeder" cloud. Rain from this cloud falls through the lower orographic cloud, or "feeder" cloud, and washes many of its tiny cloud droplets out. This makes hilly coastal land wetter than lower coastal areas.

SNOW, ICE PELLETS AND HAIL

The three main types of solid precipitation are created by frozen water. Hailstones, a common feature of thunderstorms, occur most frequently in spring or summer, while snow and ice pellets are usually – but not always – confined to winter.

SNOW

Cloud: Cumulus and stratus

Duration: Brief showers to a few hours

Intensity: Light to heavy

Snow forms when ice crystals in clouds stick together to become snowflakes. Some become heavy enough to fall to the ground. Snowflakes that descend through wet air slightly warmer than 0°C (32°F) will melt around the edges and stick together to produce big flakes. Snowflakes falling through cold, dry air produce powdery snow. Combined with winds, snowfall can create blizzards or drifts.

ICE PELLETS

Cloud: Tall cumulus

Duration: Brief showers, occasionally prolonged

Intensity: Light to heavy

Ice pellets form when snowflakes start to melt as they fall from the cloud, then fall through sub-freezing air, where they re-freeze into grain-like particles. Sometimes the snow only partially melts and falls as snow pellets, encased in a thin layer of solid ice. They are usually smaller than hailstones.

HAIL

Cloud: Cumulonimbus

Duration: Short-lived, tens of minutes

Intensity: Light to heavy

Hail is a shower of round or irregularly shaped pieces of ice formed inside cumulonimbus clouds. Small ice particles or frozen raindrops are caught in the updraught of air inside the cloud. On ascent, they gather water on their surface. Their size depends on how strong and extensive the updraught is, and the cloud's water content. Eventually, they become so heavy that they fall to the ground. Hailstones can grow up to 150mm (6in) in diameter.

DEW, FROST AND FOG

When the ground cools quickly on still, clear nights, water vapour in the air can condense into water droplets creating dew, or ice crystals producing frost. The temperature at which this happens is known as the dew or frost point respectively. Fog is the result of water droplets being suspended in the lower atmosphere, reducing visibility to less than 1,000m (3,300ft).

DEW

Weather: Anticyclonic, light winds, clear sky, temperature above 0°C (32°F)

Appearance: Very small water droplets on, for example, blades of grass

Dew usually forms during the calm weather associated with high-pressure systems. The process of dew settling from the lower layers of the air is known as "dew-fall". Up to 0.5mm (1⁄50in) of dew can form at night in some climates, averaged over the year.

HOAR FROST

Weather: Anticyclonic, light winds, clear sky, temperature at or below 0°C (32°F)

Appearance: Small, feathery ice crystals on vegetation such as leaves and grass

Hoar frost is a type of ground frost formed by ice crystals shaped like needles or feathers. It forms when water vapour in the air condenses onto a surface with a temperature below 0°C (32°F).

RIME FROST

Weather: Windy at higher elevations, with supercooled water droplets present in fog or cloud

Appearance: Opaque, milky accretion upwind of, for example, fence posts and wire

Rime frost is formed from tiny fog or cloud droplets. These supercooled droplets freeze when they come into contact with cold surfaces, forming thick, white frost. Rime frost often occurs in exposed places, usually on higher ground. The fog droplets may freeze instantly on contact with an object, building up on the windward side as a thick layer of white ice that may be many centimetres deep. This process is known as “riming”.

RADIATION FOG

Origin: Humid air, light wind, clear sky

Location: Inland (autumn and winter mostly)

Visibility: Less than 1,000m (3,300ft)

The cooling required to produce radiation fog is caused by the Earth radiating heat at night.

The weather conditions that promote the formation of radiation fog are clear skies (to boost heat loss), and calm or near-calm wind conditions. The layer of air near the ground must be humid so that the cooling will reduce the air temperature to its dew point – the point at which water vapour condenses into water. These conditions occur most commonly inland in the autumn and winter.

ADVECTION FOG

Origin: Swiftly moving, mild air over cool surface

Location: Over sea (spring, early summer) and snow

Visibility: Less than 1,000m (3,300ft)

Advection fog forms when relatively warm and damp air blows across a cooler surface, and requires fairly swiftly moving air to form. The air loses heat to the cooler underlying surface, usually sea or snow. Sea fog forms most commonly when the sea is cool during spring and early summer. Advection fog is also common when a warm front passes over snow.

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